Analysis and Modeling of Radar Surface Signatures of Non-Linear Internal Waves

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LONG-TERM GOALS

The long-term goal of this project is to understand microwave surface signatures of internal waves in the ocean so that they can be remotely detected and better predicted.

SCIENTIFIC OBJECTIVES

The scientific objectives of this research are 1) to understand the transition from the linear perturbations of surface waves by internal waves studied in the past to the non-linear perturbations embodied by wave breaking, 2) to determine the conditions that make microwave surface signatures of internal waves visible, and 3) to understand better the generation, propagation, and dissipation of internal waves on the ocean

APPROACH

Our approach is to utilize the data collected in the first three years of the NLIWI project to determine the characteristics of internal wave signatures, model the expected changes in surface waves caused by internal waves, predict the resulting microwave backscatter, and, finally, compare the modeled backscatter with that observed. The available data include those from satellite, aircraft, and ships at a variety of incidence angles and copolarizations. For the shipboard data, coincident and collocated subsurface velocities and winds are available; for the airborne data, this is also nearly the case; for the satellite data, it is not the case. Our modeling effort centers on the conservation of wave action for waves longer than about one meter, augmented by a breaking model at shorter wavelengths. Our main concern is to understand for what incidence angles and polarizations breaking wave effects become important in microwave internal wave signatures.

WORK COMPLETED

Please note that funding for this project was not received at the University of Washington until the end of June 2008. Nevertheless, we have completed some work on the project.

Our report last year showed that in our shipboard data at HH and VV, HH normalized radar cross sections (NRCSs) were not only modulated more by internal waves than VV but also became larger than VV near the crests of the internal wave. Figure 3 of last year’s report, which shows this feature is reproduced below as Figure 1:

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14. ABSTRACT
The scientific objectives of this research are 1) to understand the transition from the linear perturbations of surface waves by internal waves studied in the past to the non-linear perturbations embodied by wave breaking, 2) to determine the conditions that make microwave surface signatures of internal waves visible, and 3) to understand better the generation, propagation, and dissipation of internal waves on the ocean

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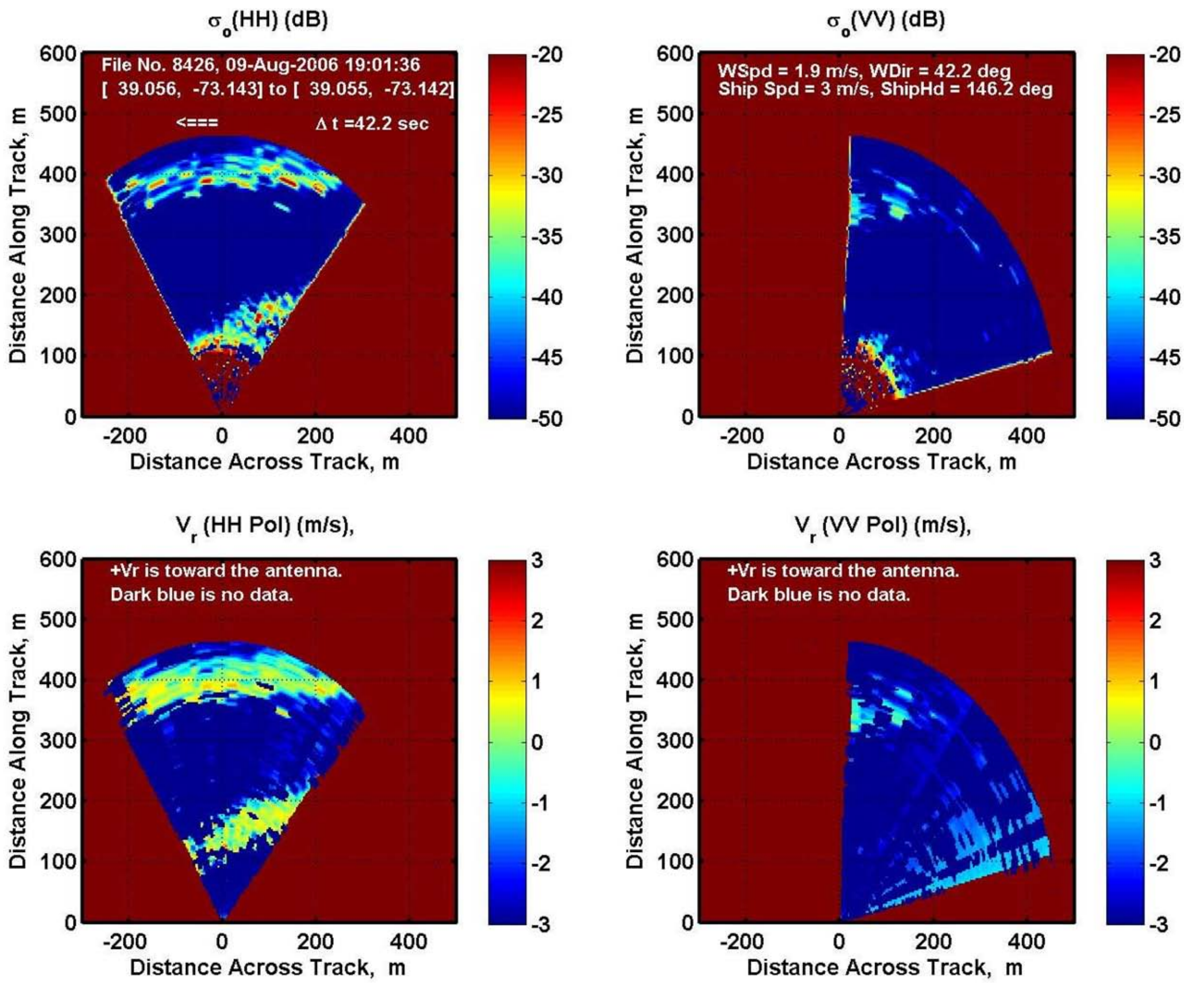

Figure 1. Images of internal waves on the New Jersey shelf obtained with the shipboard RiverRad. Incidence angles were near 88^o. Left column: HH polarization, right column: VV; Top row: cross sections, bottom row: velocities.

As we pointed out last year, not only are the cross sections larger near the crest of the internal wave, the velocities are much larger also. This is a clear indication that the backscatter near the crest region involves roughness associated with breaking waves and that their effect is more pronounced for HH backscatter than for VV. These roughness patches travel at nearly the speed of their parent breaking wave and, therefore, much faster than their intrinsic phase speed.

In view of this observation, we decided to investigate the degree to which standard composite surface scattering theory augmented by intermediate wave modulation, the multiscale model (Plant, 2002) , could account for copolarized microwave backscatter in ambient seas. Our preliminary result is shown in Figure 2 for the single case of an 8 m/s wind speed.

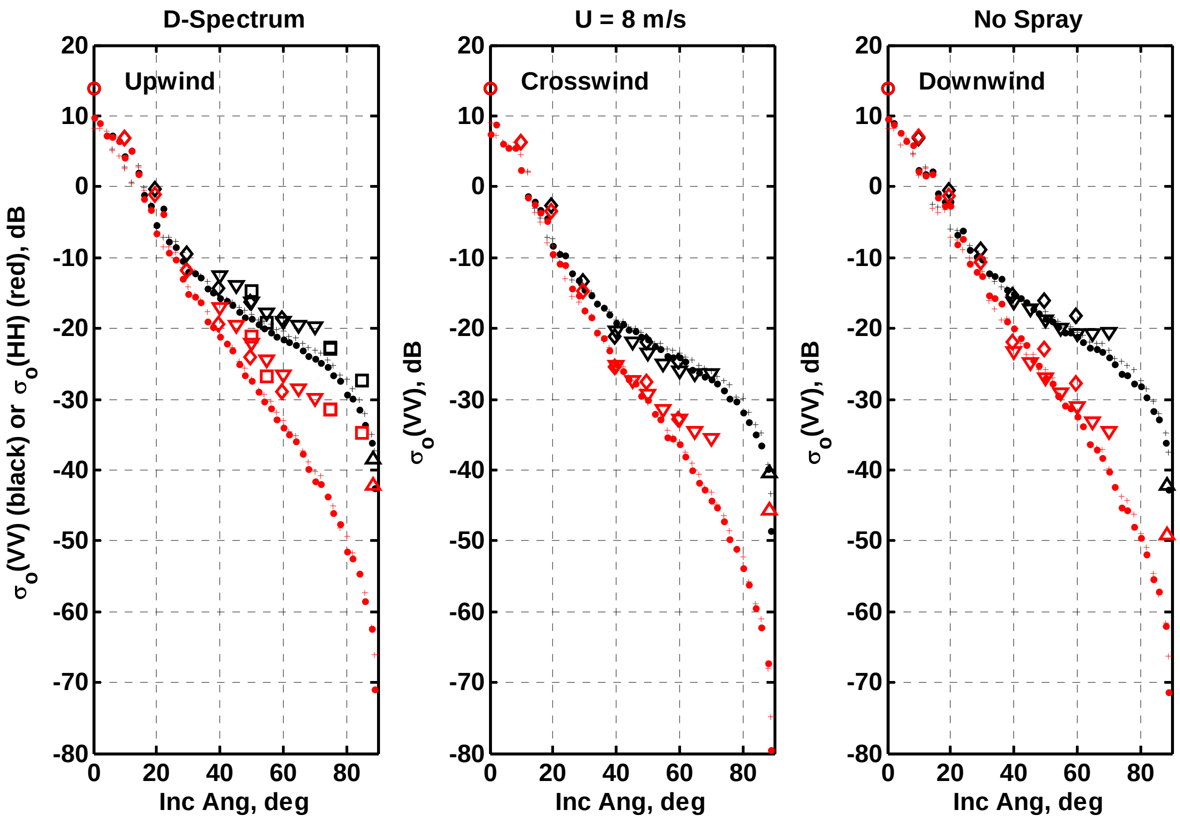

Figure 2. Comparison of predictions of the multiscale model with data for a wind speed of 8 m/s. Dots are predictions at Ku-band while circles are predictions at X-band. Red always indicates σ_o(HH) while black is σ_o(VV). Symbols for data are as follows: circles – Ku-band data from the TOPEX/Poseiden altimeter (Hwang et al., 1998); diamonds – Ku-band from an airship (Plant et al., 1998); down triangles – X-band from an airplane (Plant et al., 2004); up triangles – X-band shipboard data from NLIWI.

The striking feature of these plots is that the multiscale model fits the VV data rather well all the way out to incidence angles of 88^o but that HH data begin to lie above model predictions at about 50^o incidence.

Our hypothesis is that this excess HH backscatter is caused by breaking waves. Many processes have been proposed in the past to model backscatter from breaking waves. Several of these are shown in Figure 3. Of these processes, only double-bounce backscatter from the water surface can explain our observation that HH NRCS values exceed VV values near the crest of internal waves. We have therefore chosen the simple dihedral corner reflector of Trizna and Lee to represent this type of backscatter and attempted to model the NRCS of these reflectors for HH and VV backscatter. The result is shown in Figure 4.

Our problem now is to establish a viable criterion for when such structures might be produced by a sea surface, either disturbed by internal waves or not, to decide on a reasonable size distribution and orientation for the structures, and to establish a probability distribution for the density of these structures that are produced in various situations. Finally, we need to apply these dihedral characteristics to a modeled sea surface disturbed by internal waves.

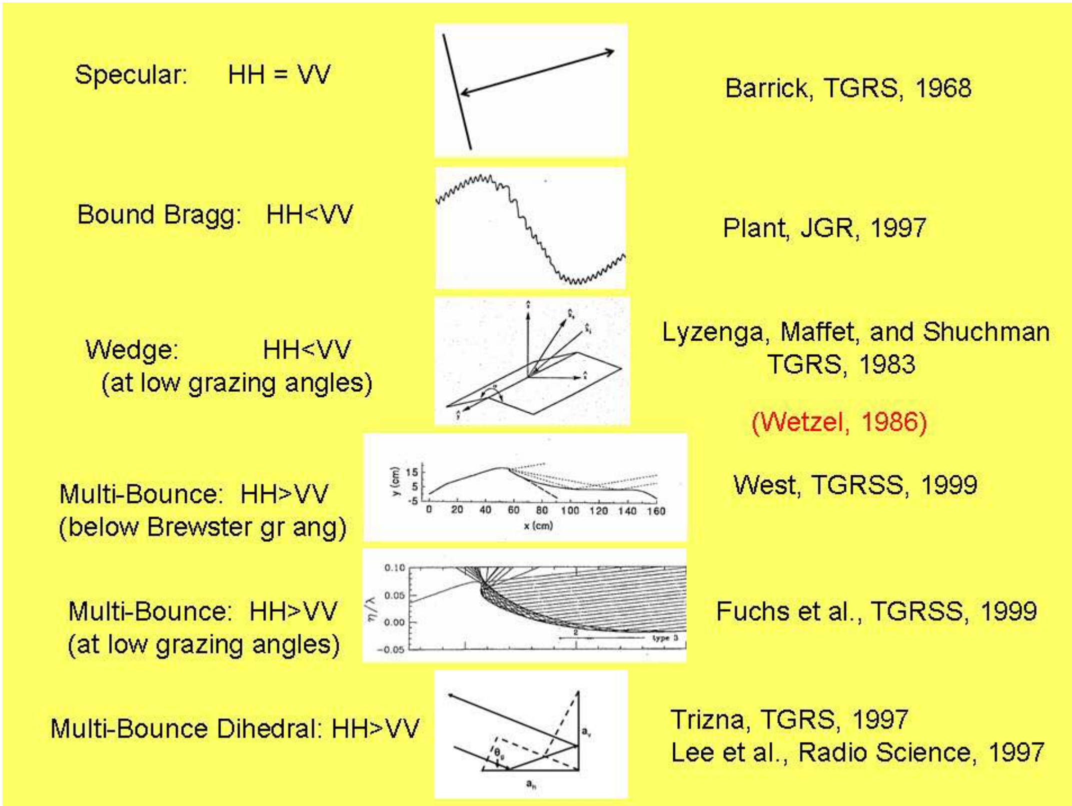

Figure 3. Various types of backscatter from breaking waves that have been proposed.

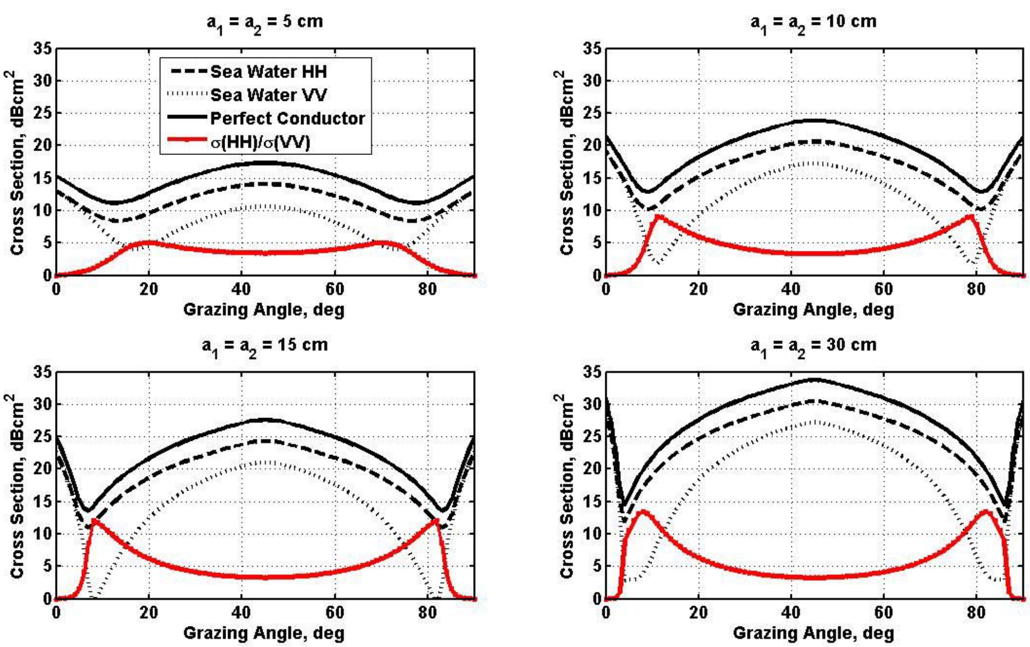

Figure 4. Cross sections of dihedral corner reflectors of various sizes as a function grazing angle. The red curves are HH/VV polarization ratios in dB. The width of the dihedral is 1 cm. a_1 is the length of the horizontal plane while a_2 is the length of the vertical plane.

IMPACT/APPLICATION

This study will help establish the relationship between remotely observed microwave signatures of internal waves on the sea surface and the properties of the internal waves. This will aid in the prediction of internal wave location and amplitude for use in submarine navigation and acoustic propagation calculations in the internal wave field.

TRANSITIONS

The results of this project have not yet been transitioned for operational use.

RELATED PROJECTS

This project is part of the NLIWI experiment and is strongly related to the WISE/VANS experiment and to the Surface Wave 06 acoustic experiment.

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